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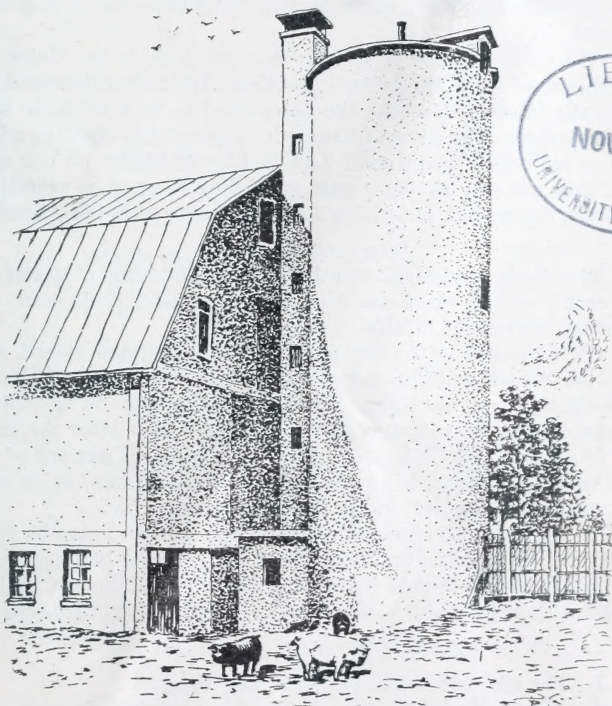
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THE SILO

ITS CONSTRUCTION, CAPACITY AND COST

BY F. W. IVES



Monolithic concrete silo

EXTENSION BULLETIN

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THE SILO

By F. W. IVES

FOREWORD

The purpose of this bulletin is not to urge the use of silos nor to discuss the economy of silos as an aid to the feeding of livestock; rather it is designed as an aid in the proper selection of a silo from among the many good types in use, both home-made and commercial.

The successful use of the silo in every state in the Union has demonstrated its utility beyond question. The dairyman should be especially interested, as the silo has proved to be a veritable year-round pasture. The silo was largely instrumental in enabling stockmen to introduce "baby beef" and "hot-house lambs" to our markets, thus not only saving a year of feeding to produce practically the same live weight, but giving a higher quality of finished product.

THE SILO DEFINED

The silo is an airtight vessel for the preservation of green forage crops, among which are corn, sorghum, peas, Kafir corn, rye, soybeans, clover and alfalfa.

Corn seems to be the best ensiling material of any named, as it is easier to pack and thus exclude air, which might cause excessive fermentation and consequent lowering of the value of the silage. The process of fermentation takes place very soon after the material is placed in the silo, and takes away about 3 percent of the food value of the corn as compared to a loss of 35 percent or more where the fodder is left in the shock until December.

The silo may be almost any shape and size, and may be made of various materials, practically all of our common building materials having been used in its construction. The limitation modifying the above statement will appear in the following discussion.

REQUIREMENTS OF A GOOD SILO

1. The silo must be above all things airtight.
2. It logically follows that it should be waterproof.
3. It should have a good and sufficient foundation to prevent uneven settlement of the walls and consequent injury of the structure and its contents.
4. The inside surface of the walls should be smooth and perpendicular.
5. The walls should be strong enough to withstand the immense outward pressure caused by the silage.

6. Sufficient openings should be provided for the easy removal of the contents.
7. A roof should be provided as an aid to the preservation of the silage and the building itself, and to give a finished appearance to the structure, altho the roof is not considered absolutely essential.
8. A chute, to prevent the scattering of the silage when thrown out, should be provided.
9. The height of the silo must be from $2\frac{1}{2}$ to 3 times its diameter in order to pack the silage tightly for its preservation.

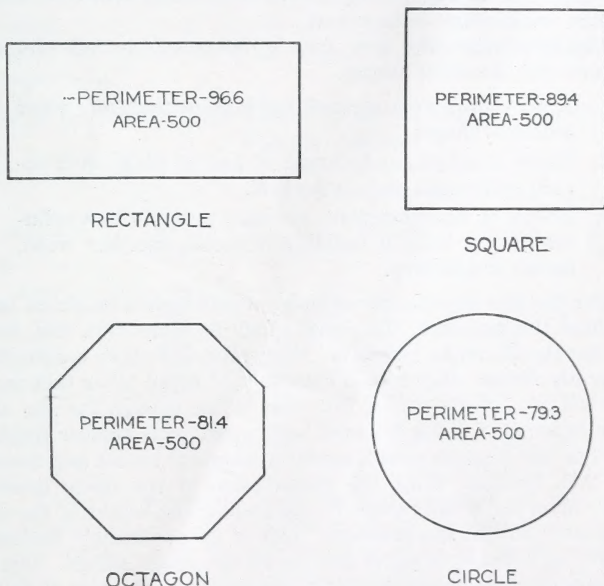


Fig. 1. The round silo encloses the most area for the least perimeter

SHAPE OF THE SILO

All manner of shapes have been used for silo construction. The Mexicans use an adobe urn-shaped affair; long narrow pits were used in early experiments; shallow, oblong stone cellars were used by some of the pioneers of silo construction, but the round silo has demonstrated beyond doubt that the cylinder is the proper shape both for economy of construction and utility in preserving the silage. Fig. 1 shows the comparison between different shapes and

their areas and perimeters, to illustrate how the circle encloses the most area for the least perimeter.

Early silos were built of both wood and stone, in square or rectangular form, but it was soon found that the square corners caused a great deal of spoiled silage, since it was practically impossible to tramp it properly at these points. More or less air was imprisoned, and mold and decay caused much loss. Some of these silos were later improved by rounding the corners. The square form is very difficult to reinforce against bursting pressure. The flat walls, especially of the wood construction, are likely to bulge and thus form air pockets, or at least cause uneven settlement, either of which would be detrimental to the silage.

The cylindrical silo, then, may be conceded the following advantages over the other shapes.

1. A given wall area incloses more space than any other practical shape.
2. There is not so much danger of loss of silage thru uneven settlement and air pockets.
3. Hoops, or reinforcement, are easy to apply to a cylinder of any kind of building material, whether wood, metal, or masonry.

For the best success, the cylinder should have a height at least $2\frac{1}{2}$ times the diameter. The height may be more than this, however, but should not be excessive. Many silos have been constructed apparently for no other reason than that of being taller than some other tall silo. Forty-five or fifty feet is tall enough for any silo, as the expense of filling becomes very great with greater heights, and when the silage is used it means a laborious ascent and descent with each feeding. Since the compression of the silage depends largely upon the weight above it, the greater the height of the silo, the greater will be the pressure. This is an exceedingly desirable feature, as it helps to expel the air as the silage settles. Due to this same compression, more silage can be stored per foot of height in a tall silo than in a short one.

SIZE OF THE SILO

Before purchasing or erecting a silo, some notion as to the proper size should be obtained by study of the conditions it must meet. A silo which is too small is really better in one sense than one which is too large, for while the former will not contain enough feed, the latter will cause waste of good feed. While there is little limitation on the height other than that discussed in the previous

paragraph, there is a practical limitation on the diameter, namely, the quantity of silage to be fed off each day. When silage is exposed to the action of the air, decomposition sets in. There is but little action in the interval between feedings; however, there should be about 2 inches removed from the entire exposed surface every 24 hours in cool weather and about 3 inches removed in the same period during warm weather. It can be readily seen, then, that if one has not sufficient livestock to consume this amount daily, there will be more or less waste.

Table I, which is reproduced from Farmers' Bulletin 855, shows the relation of the size of herd to diameter of silo for winter feeding, based on 40 pounds of silage per cubic foot. (Note: 40 pounds per cubic foot is the mean weight of settled silage in the average silo.)

TABLE I.—RELATION OF SIZE OF HERD TO DIAMETER OF SILO, FOR WINTER FEEDING

Inside diameter of silo	Quantity of silage in depth of 2 inches	Number of animals that may be fed, allowing—			
		40 pounds per head	30 pounds per head	20 pounds per head	15 pounds per head
FEET	POUNDS				
8	335	9	11	17	22
10	524	13	17	26	35
11	634	16	21	31	42
12	754	19	25	37	50
13	885	22	29	44	59
14	1,026	25	34	51	68
15	1,178	29	39	59	78
16	1,340	33	44	67	89
18	1,696	42	56	85	113

From the foregoing table, we may see that for the smallest practicable silo, 8 feet diameter, at least the equivalent of 9 full-grown animals must be maintained in order to use the silage fast enough. It is hard work to throw the silage from a silo more than 16 or 18 feet in diameter without twice handling. In summer, or in warm weather, a half more silage must be used over that given in the second column of Table I.

Table II, from the same Bulletin, shows the amounts of settled silage expressed in tons for different diameters of silo. Note that the *height is the depth of the silage after settling and not the actual height of the silo.*

It is possible, from the data given in the two tables, to buy or to build the silo that will meet both the question of proper size and height economically.

TABLE II.—DEPTH OF SILAGE (AFTER SETTling) FOR A GIVEN CAPACITY OF SILO WITH A GIVEN DIAMETER

Depth of silage (after settling 2 days)	Capacity of silo having an inside diameter of—							
	10 feet	11 feet	12 feet	13 feet	14 feet	15 feet	16 feet	18 feet
FEET	TONS	TONS	TONS	TONS	TONS	TONS	TONS	TONS
24	34							
26	38	46	55					
28	42	51	61	71	83			
30	47	56	67	79	91	105		
32		62	74	86	100	115	131	
34			80	94	109	126	143	
36			87	102	119	136	155	196
38				110	128	147	167	212
40					138	158	180	228
42						170	193	245
44							207	262
46								280

Theoretically, a large building will inclose space more cheaply than a smaller one. However, when we consider the loss of silage that might occur from the use of a large diameter silo, it will be found that two small or medium-sized silos may be cheaper than one large silo. Suppose, for example, we desire to feed 14 cows during the entire year. At a good ration, this would require about 100 tons of silage. We might, by looking at Table II, choose a silo 13 by 36 feet or a silo 14 by 32 feet. However, by a study of Table I, we see that a silo 10 feet in diameter would be the correct size, if we are to keep the silage from spoiling. Turning back to Table II, we find that two silos 10 by 30 feet will give us the desired capacity. However, as this represents the depth of settled silage, we must add about 4 feet to the height, making our final choice two silos 10 feet in diameter and 34 feet high.

FOUNDATION

Having decided upon the size of silo, the next consideration is the foundation. This is an important matter, as a good foundation is essential to the success of the silo for many reasons. Uneven settlement, due to insufficient foundation, may result in a cracked or warped silo, a silo out of plumb, or even the overturning of the structure. Cracking or warping both cause spoiled silage. A silo out of plumb results in uneven settlement and air pockets, either of which causes spoiled silage.

The three factors governing the design of foundations are the nature of the soil, the weight of the structure and its contents,

and the strength of the foundations. In tall structures such as silos, wind pressure may also become an important factor, as the foundation must withstand a large portion of the overturning thrust.

Drainage, either natural or artificial, is important, as twice the load will be supported on a given area of dry soil that would be supported when the same area is wet. This may be illustrated by the familiar condition of an earth road when wet and when dry. The load on the silo foundation might, without thought, be assumed as merely the weight of the silo walls; there is enough friction between the walls and the silage so that the load is increased considerably—an amount hard to determine, however. The vertical component of the force exerted by the wind on the side of the silo is considerable, and, at the foundation, is greatest on the side opposite the one from which the wind comes. Allowing for unusual soil conditions, the foundation walls may be made as heavy for one type of silo as for another. In fact, it

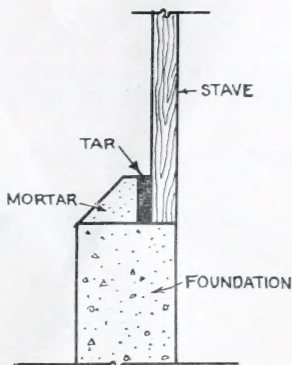


Fig. 2. Method of protecting joint between wood silo and any type of masonry foundation

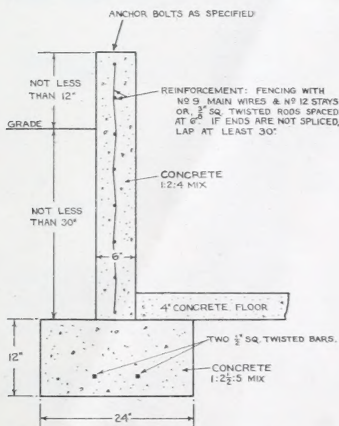


Fig. 3. Silo foundation of concrete, for soft or wet soil conditions (may be adapted to any type of silo)

may be well to design the foundation of a wooden silo heavy enough to bear a masonry silo, so that in case the wooden silo is replaced by one of the heavier type silos, the expense of remodeling the foundation will not be necessary. The foundation should be extended below frost line. For Ohio, this distance will average about 30 inches below grade. Where the soil is gravelly or loose, the frost may penetrate 4 feet. Where the foundation wall is carried 3 or 4 feet below grade, the earth should be excavated to

form a pit the depth of the foundation, thus adding greatly to the capacity of the silo without materially increasing the cost. Too great a depth is not desirable, as it increases the labor of getting out the silage near the bottom.

FOUNDATION MATERIALS

The materials of permanent nature most nearly at hand are suitable for silo foundations. Brick, stone, and concrete are most commonly used. Some manufacturers of tile and concrete block silos use those materials for foundations, but usually provide a footing of monolithic concrete. Concrete is probably the most widely used footing and foundation material, as it can be handled by anyone who will follow a few simple directions that may be obtained

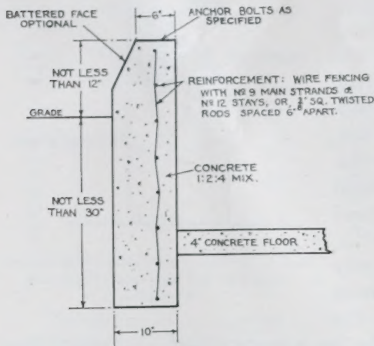


Fig. 4. Silo foundation of concrete, for well-drained or solid soil conditions (may be adapted to any type of silo)

from any cement organization. Moreover, it is quite easy to install reinforcing steel and foundation bolts in concrete. Where a little care is taken in proportioning, mixing and placing, the concrete becomes practically one stone, and is very nearly, if not quite, waterproof.

Unless the concrete is poured into a smooth trench it becomes necessary to provide forms. These may be quite expensive or quite cheap, according to the method and manner of using. Typical concrete foundations are shown in Fig. 3 and Fig. 4. Variations may be made if necessary.

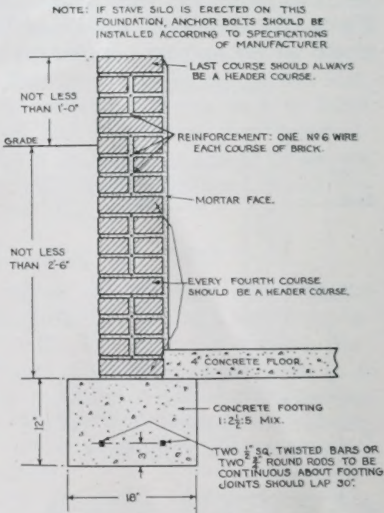


Fig. 5. Silo foundation of brick (may be adapted to any type of silo)

Brick or rubble may be used with good success where they are easy to obtain, and where perhaps concreting materials are

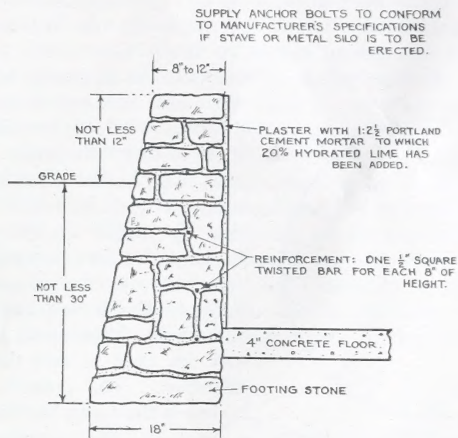


Fig. 6. Foundation of native field stone rubble masonry
(may be adapted to any type of silo)

not available. The chief advantage of these materials is that no forms are necessary. This is partially counterbalanced by the fact that specialized skilled labor is necessary for their rapid construction. Fig. 5 shows a typical brick foundation wall, while Fig. 6

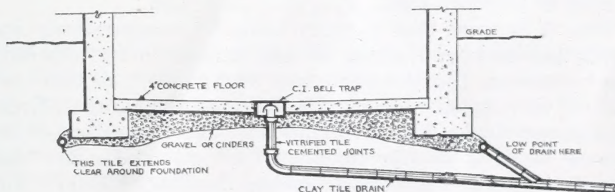


Fig. 7. Drainage for silo and foundation

shows a rubble-stone masonry wall. Both these walls should be reinforced, as noted in the drawings. Where drainage is necessary, it may be provided as shown in Fig. 7.

WHY THE SILO AND ITS FOUNDATION MUST BE REINFORCED

A liquid presses outwardly on the sides of a containing vessel in direct proportion to the weight of the liquid and the depth of

the liquid at the point where the pressure is taken. For example, water weighs approximately 62.4 pounds per cubic foot. At a depth of 10 feet, the pressure on the side of a tank would be 10×62.4 , or 624 pounds per square foot. If the point taken is 20 feet below the surface, then the pressure will be 20×62.4 , or 1248 pounds per square foot. If the tank is cylindrical, the pressure will be out-

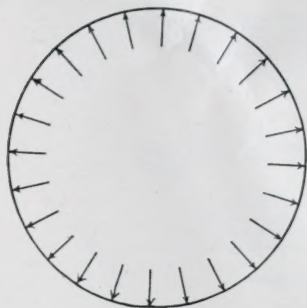


Fig. 8. Diagram showing how internal pressure tends to burst a tank or silo

ward and equal at any horizontal section, with a result that it *tends* to burst the tank. The pressure acts in the direction of the arrows shown in Fig. 8. If we divide the circle in two parts, we see that the forces represented by the arrows acting on one half are equal to the forces acting on the other half. This would be true any way we care to run our dividing diameter. The result of these forces is the force tending to break a hoop or the material of the tank.

Owing to the different nature of silage as compared to water, in that it is not as elastic and does not press outwardly as strongly as the water, the outward pressure on a silo wall is taken to be about 11 pounds per foot of depth as compared with water at 62.4 pounds per foot of depth. Nevertheless, the pressure is considerable and must be provided for.

Now it happens that masonry walls are comparatively weak for resisting the kind of stress we find in hoops, altho very strong against crushing. This deficiency may be supplied with steel hoops, as steel is very strong when used in this manner. Many failures in early masonry tanks, bins, and silos were due to the lack of these accessory hoops or reinforcements. Wood stave silos had hoops, but these were only considered as holding the staves together, when, as a matter of fact, they also took care of the bursting forces as well.

Hoops are now applied to masonry silos, altho usually in the form of wires or rods inclosed in the walls of the structure instead of being exposed as in the case of wood and concrete stave silos. It is a fact that practically all silo failures may be traced back to a lack of understanding of the stresses involved and the materials employed, rather than to any inherent defect in the material.

ROOF

Users of silos are nearly unanimous in saying that the roof is desirable but not essential. In an investigation on this subject, in which some 200 silo users participated, the following statements were given: "The roof gives a finished appearance to the structure." "The roof adds to the life of wooden silos, more particularly the home-made types." "The roof aids in preventing freezing of the silage in winter." "The roof adds materially to the comfort of the person taking out the silage." The two most popular arguments against the roof were, (1) that "the roof adds to the cost of the structure," (b) that the "silo may not be filled to capacity with the roof in the way." There is, of course, no answer to (a), but to (b) we may answer by saying that there are many commercial folding roofs which actually add to the capacity of the silo. The gambrel roof may also be used for adding capacity. A study of Fig. 9 will show the relation of roof forms to the head room re-

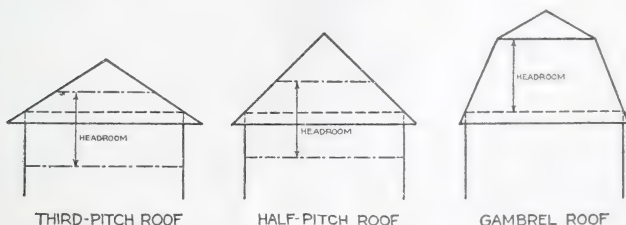


Fig. 9. Space gained by different roof forms

quired for tramping the silage. On concrete and tile silos, a monolithic concrete roof is sometimes built. Where a frame roof is used, due care should be exercised to secure the roof to the structure, as at the height of the roof, the wind has a clean sweep and occasionally attains a fairly high velocity and is likely to wreck any loose construction. With masonry silos, bolts similar to foundation bolts may be used to secure the plate.

For the purpose of filling, dormer windows, scuttle windows, or removable sections must be provided. With a folding roof, this is not necessary. Ventilator tops are sometimes added. This is important, mainly where the silo and its chute are used as auxiliary ventilation shafts in connection with the stable. Lightning rods may be added with good effect, as the silo is apt to be the tallest structure in the group of farm buildings and hence somewhat more likely to be struck by a lightning bolt.

DOORS AND DOORWAYS

Doorways for the silo may be continuous or spaced. Continuous doorways are a great advantage when removing the silage, as there is no uphill pitching necessary. Some firms manufacture silos with a staggered doorway, which, in effect, is a continuous doorway so far as getting out silage is concerned, yet not continuous from top to bottom, which is thought by some to detract from the

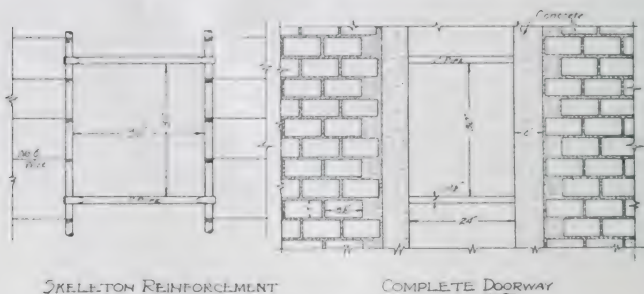
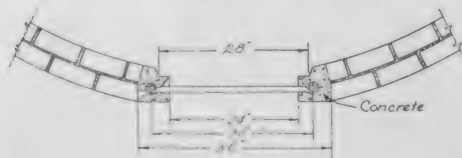


Fig. 10. Doorway in paving brick silo

strength of the silo. Every silo should be constructed so that the reinforcement about and across the doorways is fully equal or superior to the reinforcement elsewhere.

Spaced doorways should not be too far apart, as the labor of getting out the silage is thereby increased and in filling time there is more danger from carbon dioxide gas. This gas is heavier than air, and will settle in the silo below the bottom of the lowest opening. It is generated at filling time, and especially overnight. If doorways are spaced widely, or doors are left closed and the silage settles, the lowest opening may be above the head of a man who, jumping in, may be asphyxiated in a short time. There is no danger where the gas can flow out.



HORIZONTAL SECTION OF DOORWAY

Fig. 11

The doors may be single or double ply, with waterproof paper. Double ply doors or doors of tongue-and-groove material are recommended, as the doors must be air-

tight. They should fit the openings snugly. The writer has found that common clay mixed to the consistency of putty makes an excellent seal around and between doors. Commercial doors of excellent type may be secured. Among the best are those arranged in slides or upon hinges. This feature is not absolutely essential, but saves much bother in storing, with its accompanying breakage and labor. The reinforcement running across the doorway may be utilized as a ladder. One or two farmers have recently installed very ingenious elevators for getting up and down.

CHUTE

The chute, along with the roof, cannot be classed as essential, but it is extremely desirable. The chute is a boxlike inclosure in front of the doors and extends from the top of the silo downward to a point just a convenient distance above a man's head. It prevents the scattering and blowing of the silage when thrown out, and aids in protecting the door and preventing freezing. The chute may be used as a hay chute when built between barn and silo and may also be utilized as a convenient flue for stable ventilation. It adds much to the safety of the individual who ascends and descends the ladder. No great expense need be incurred in its construction, but it is very desirable that an occasional window be installed to aid in lighting both chute and silo. Many types of silo have a built-in chute. Many inexpensive chutes are constructed of sheet metal.

PROTECTIVE COATS FOR SILOS

Farmers' Bulletin 744, on the Preservative Treatment of Farm Timbers, makes the following statement: "A thoro treatment with coal-tar creosote will make a wooden silo more resistant to decay and less subject to shrinking and swelling. It will also make painting unnecessary. * * * Some manufacturers are already doing this, and it is now possible to purchase a pressure-treated silo all ready to set up. * * * One possible objection to the use of creosoted lumber in silos is that the silage might be contaminated by creosote bleeding from the wood. Information obtained from the Forest Service, however, indicates that there is little danger of this if proper care is used. In order to prevent contamination, the treated wood should be thoroly air-seasoned in open piles after it is treated and before it is put into the silo. * * * Of the woods in general use for silo construction, the pines are, as a class, the most easily treated; hemlock, tamarack, spruce and Douglas fir are somewhat more difficult. With pressure treatment the greatest saving can

usually be effected by using the cheaper woods, as the difference in durability of the various species is less after treatment than before. It is questionable if the treatment of such durable species as heart redwood and heart cypress would pay."

Treatment other than creosote for wooden silos consists in painting the exterior with a good linseed oil paint in the same manner as with any other exterior wood surface. The interior may be painted with coal tar thinned with gasoline.

Concrete and masonry silos have been treated successfully with a wash of cement and water mixed to a creamy consistency. This wash is best applied when the structure is new. Tar thinned with gasoline or benzine, hot tar or asphaltum, paraffine, or water glass are other materials used for protective coatings. Treatment is not always necessary.

FREEZING OF SILAGE

Correspondence with some 200 silo users in Ohio brought out the fact that regardless of type or make of silo, silage would freeze in cold weather. Many arguments are advanced in favor of this or that silo "because it will not freeze." It is true that certain silos, because of double walls or walls inclosing an air space, will not freeze quite as readily as a thin single-wall silo. The relative conductivity of the material also has some effect on the time in which freezing will occur. Freezing is not so serious, as frozen silage may be fed safely if first thawed. It is true that it will deteriorate much sooner than other silage, but it may be fed as soon as thawed and thus avoid losses. The roof and chute will do much to prevent freezing. A farmer corresponding with the "Ohio Farmer" states that he reduced freezing to a minimum by keeping the silage in a somewhat conical shape, keeping the sides lower than the center.

THE SILO AS A SUPPORT FOR OTHER STRUCTURES

When planning to build or purchase a silo, due consideration must be given to its use for purposes other than a silo. Frequently, feed or grain bins are supported between the silo walls; water tanks may be erected, using the silo as a base, or it may become the central supporting member of a round or octagonal barn. Obviously, where such heavy loads are thrown on the silo walls, the walls and foundations must be designed to carry them. It is generally true that a masonry silo is better able to take such loading, a wood stave silo ordinarily being too unstable. Concrete, tile, brick, and concrete block silos have been used successfully as tank supports.

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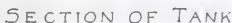


Fig. 12. A tank of reinforced concrete

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KINDS OF SILOS

WOODEN SILOS

Wood has ever been a popular building material on account of its availability and easy working qualities. Its use for large tanks

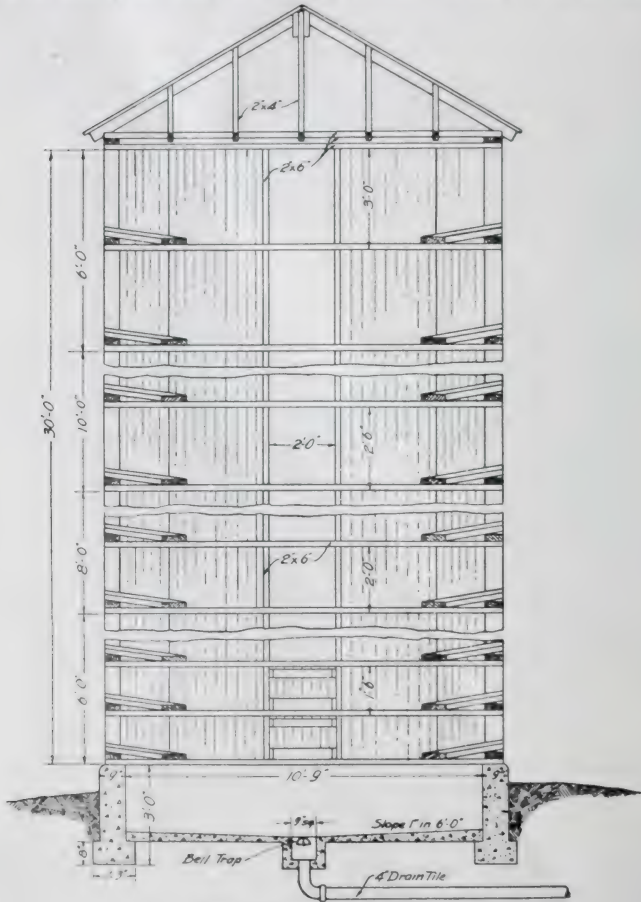


Fig. 13. Home-made wooden silo

no doubt led to its early use as a silo-building material, for the silo is essentially a tank. Wood is used in both home-made and commercial types of silos. The commercial type of silo outnumbers the

Bulletin 100, Iowa Agricultural Experiment Station, the relative durability of timber for silos ranks as follows: 1. Redwood. 2. Cypress. 3. Oregon Fir. 4. Tamarack. 5. White Pine. 6. Long Leaf Yellow Pine. Native timber such as poplar, oak, maple, gum, elm, and ash, has been used with varying success in home-made silos, but it is doubtful if any of these would, under ordinary conditions, give results equal to the cone-bearing timbers listed above. Some home-made silos without roofs or any preservative treatment have gone to pieces so badly in 2 years as to be unserviceable. Others have been constructed inside of barns and have given service for 20 or more years. For the most part, these latter silos were lined with durable boarding, while the frames or hoops were made of cheaper native lumber.

It is doubtful economy to build a silo within another structure, for it amounts to paying for the space twice. It would be more economical in the long run to use durable materials, paint or treat it with some good preservative, and provide a roof for protection.

Other than decay, which can be lessened by proper care, the two greatest enemies of the wood silo are fire and wind. Against fire there is but little protection other than lightning rods. Against wind, guy wires or anchors should be provided. It is necessary also with most commercial wooden silos to tighten the hoops in dry weather or when the silo stands empty, so that it will not collapse. We are all familiar with what happens to a wooden pail when it dries out. When the silo is again filled and the staves become swelled with the silage juice, it is necessary to adjust the hoops by loosening, so that the swelling will not cause the staves to buckle. Treatment of the staves will tend to prevent both shrinkage and swelling, as the pores of the wood will be nearly filled with the preservative. Wooden hoop silos are not so troublesome, as the staves are generally nailed to the hoops and form a rather substantial structure.

Two types of wood-constructed silos are shown in Figs. 13 and 14. These are essentially home-made silos. A commercial type of wood stave silo is illustrated in Fig. 15.

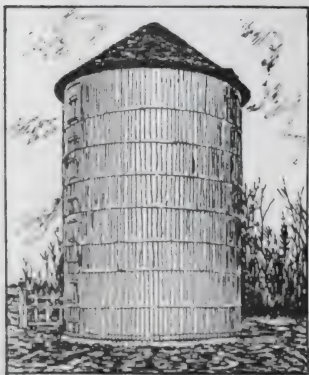


Fig. 15. Wood stave silo

Commercial wood silos are made either in one-piece or two-piece staves usually. One-piece staves are preferable in some respects, as there are fewer joints. However, the height of the silo is limited by the length of the stave and, therefore, for tall silos, two-piece staves are used. The two pieces are joined with a butt joint, which should be tongued and grooved or secured with a steel spline. This is a point of weakness unless carefully made. These joints should be painted or otherwise treated before being set together. The tongues and grooves may be painted if desired.

Care should be taken to see that the anchor eyes are welded, as they are occasionally under considerable strain. One farmer reports that it cost \$87 to reerect his stave silo because the eye-bolt anchors straightened out from the effects of high wind pressure on the silo.

For further information on home-made silo construction, write to the United States Department of Agriculture, Division of Publications, Washington, D. C., or to your Congressman, for Farmers' Bulletin 855, entitled, "Homemade Silos." These bulletins may be obtained free of cost.

CONCRETE SILOS

Concrete is used for silo construction in several different ways. Monolithic concrete, as its name indicates, is a continuous structure, practically one stone. (See illustration on cover.) Concrete blocks are used with good success in silo construction, while concrete staves are a later development of the concrete block. Another use of concrete is in connection with metal lath or expanded metal. The metal is set up and then plastered with several coats of concrete mortar until the desired thickness is obtained.

Concrete silos have been successfully constructed by farmers as well as contractors. A good understanding of cement, concrete and good materials are all that are necessary to secure a good structure. As has been explained, a concrete silo must be well reinforced. In addition, the concrete must be well mixed and well spaded into the forms. Good concrete cannot be made without using a goodly proportion of cement. A proportion of one part Portland cement, $2\frac{1}{2}$ parts clean sand, and 3 to 4 parts good quality crushed rock or pebbles will be found to be a satisfactory mixture.

The forms for such silos may be purchased, rented, or may be built. Farmers' Bulletin 855 contains directions for the construction of forms. In order to cut down expense, it is desirable for three or four farmers to go together in making or renting forms, as the cost will then be distributed over several silos.

Some silos have been made so carelessly, either in the proportioning or placing of the concrete, that they are porous and are likely to cause large losses of silage. This condition has been remedied by washing the interior of the silo with a creamy cement wash, either one or two coats. Hot tar or tar thinned with gasoline have also been used with success. In any case the wall must be clean or the wash or coating will not stick or penetrate. The concrete silo in the main is very successful, there being but little trouble due to spoiled silage. Permanence is a feature worthy of consideration in any structure and especially in a silo. Evidence, based largely on theory and a few laboratory tests made without consideration of the practical side of silage making, is advanced to show that silage acid attacks concrete silos and the mortar joints of other masonry silos. Observation of actual silos under actual working conditions show that, after many years, there is but lit-

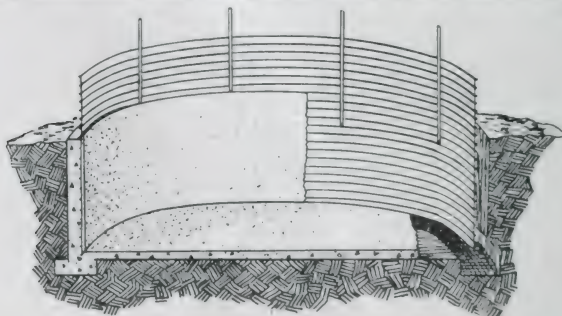


Fig. 16. Sectional view of concrete silo on expanded metal lath

tle, if any, action tending to crumble the masonry where a reasonably good mortar or concrete was used. In any event, if such action should take place the walls may be treated as outlined above for porosity. The writer has observed one silo for a period of 18 years which still has original trowel marks on the interior surface after continuous use. A neighboring silo built of stone and lined with cement mortar has been in use for nearly 30 years and is still being used, the walls being in excellent condition.

Concrete blocks and concrete staves are a manufactured product designed to cut the cost of forms. The concrete block silo is a success where the blocks are properly constructed and cured. In some types the reinforcement is built into the blocks and additional reinforcement in the form of hoops and dowel pins is placed between the blocks. In other types hoop reinforcement is laid in the mortar joint between tiers of blocks. The cement stave is a modi-

fication of the block silo. The hoops are applied to the outside, as in the wood stave silo. Usually the cement staves are thinner than the blocks, which probably accounts for the placing of reinforcement on the exterior where it is exposed to the weather. It is doubtful whether the hoops improve the appearance of the silo. These silos should be erected by competent workmen. Especial care should be taken to see that all joints are carefully filled with a good quality of mortar.

Expanded metal and concrete silos are constructed by erecting studding to

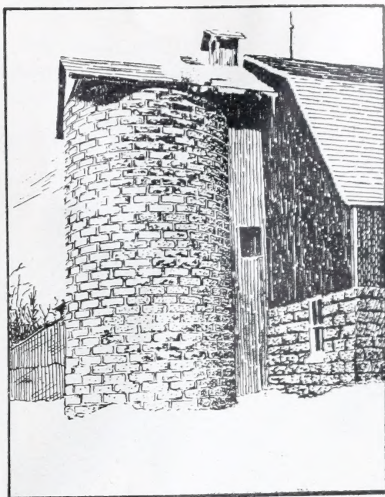


Fig. 17. Concrete block silo

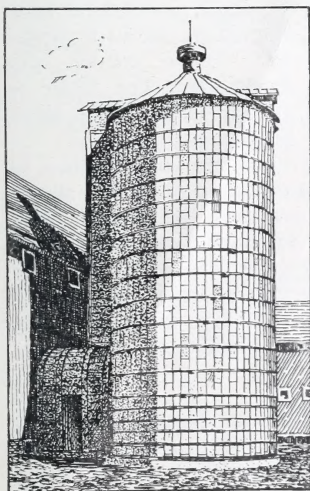


Fig. 18. Cement stave silo

which the expanded metal is fastened, the metal having been bent to the proper radius. A heavy coat of cement mortar is then applied to both sides of the metal. The temporary studding is then removed from the inside, and a finish coat of plaster applied. The wall is from 3 to 4 inches in thickness, reinforced quite thoroughly by the metal, which is very well distributed over the entire structure. Altho forms are not required for this type of silo, considerable more staging is necessary. More highly skilled labor is necessary for the application of the plaster than would be employed in the construction of a monolithic silo, but is balanced by the use of less material in the forms. A sectional view of this silo is shown in Fig. 16.

Brick is one of our oldest and most reliable building materials. Practically fire-proof and weather resistant, brick has been satisfactory in all manner of structures. Some of the earliest silos

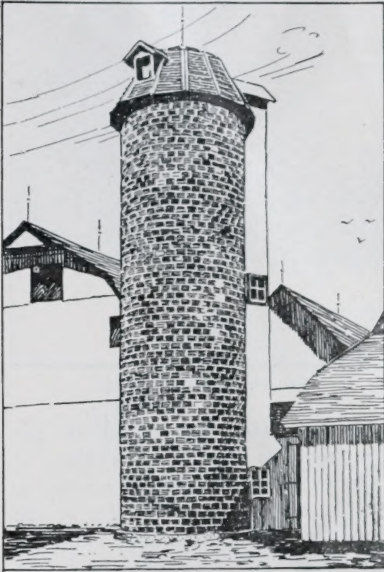


Fig. 19. Vitrified tile silo

were constructed of brick and are still giving excellent service. The hard-burned or vitrified brick are best for silo construction, as they are less porous or absorbent than common brick. A somewhat high degree of skill is necessary to handle them successfully in building circular walls and there is some difficulty in placing reinforcement. However, heavy wire may be used between courses with good results. Good mortar should be used, as the joints will otherwise prove wasteful of silage. Brick silos have been built in both single and double course wall thicknesses. The latter is recommended as being safer and better.

Hollow tile are manufactured by much the same process as brick. They have the added advantage of a dead air space, an aid in insulation. For a given bulk, they are much lighter than brick and hence easier to handle. They lay up much faster than brick, one tile replacing from four to eight brick, depending upon the size. Some tile are made with a radius to fit a desired diameter of silo and make a very fine wall. As with any type of masonry silo, reinforcement and good mortar joints are essentials.

METAL SILOS

Metal silos are a comparatively recent development. Galvanized iron and steel were first used, but conditions brought about shortly after the opening of the great war in 1914 made galvanizing materials very costly, and steel and iron silos were then

enameled or painted so as to keep the cost within suitable limits. Metal silos are very good keepers of silage and seem to be giving excellent satisfaction. Silage freezes to a considerable depth during severe weather, as the thin sheet of metal has but little insulating effect against cold. The life of the metal silo has not yet been determined, as such silos have not been in general use long enough to warrant conclusions. Some metal silos are in good shape after several seasons of use. There seems to be a decided tendency toward corrosion about the doorways where the silage is thrown against the walls at feeding time. Boiler

paint applied to the interior walls at these points will help to prevent rust from forming while the silo is empty. Metal silo manufacturers should be consulted as to the paint they recommend for their product.

Working drawings of the silos described in this bulletin may be obtained by writing to the Department of Agricultural Engineering of the Ohio State University, Columbus.

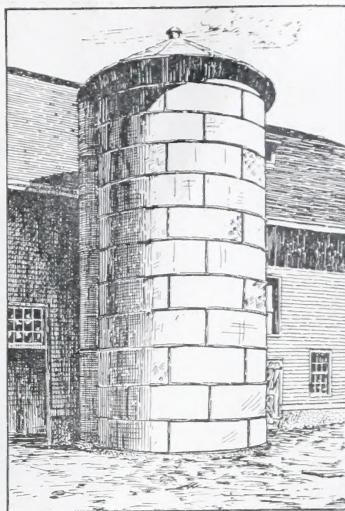
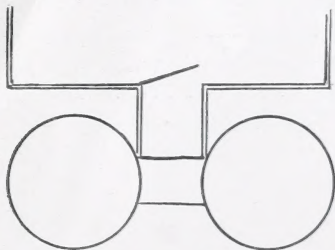


Fig. 20. Metal silo



Arrangement of two silos with one chute for economy of construction and of labor in feeding

THE COST OF A SILO

In comparing costs of various makes of silos, the only fair comparison is based on the cost per ton of capacity of the completed silo. The capacity of any silo should be compared with a standard table of silo capacities so that the results will be equitable. The cost per year is also important. This is based on interest on the investment and the life of the silo. If a silo costs \$250 and lasts but 4 years the annual charge for depreciation is \$62.50, not counting possible repairs in the meantime. If, on the other hand, a silo costs \$500 and lasts 20 years, the annual depreciation charge is but \$25, plus repairs, which are likely to be extremely small. The following items must be taken into account in finding the first cost of a silo:

- | | | |
|-------------------------------------|----------------------|------------|
| 1. Excavation. | Man and horse labor. | |
| 2. Foundation. | Man and horse labor. | Materials. |
| 3. Silo proper. | Man and horse labor. | Materials. |
| 4. Roof. | Man and horse labor. | Materials. |
| 5. Chute. | Man and horse labor. | Materials. |
| 6. All staging. | | |
| 7. Freight or other transportation. | | |

Lumber obtained from the farm should be charged at current prices. Man labor and horse labor should be charged at current prices. Prices on materials may be obtained from agents, contractors or dealers. A record of silos in the State of Ohio built previous to 1915 shows a first cost of from 75 cents to \$5.75 per ton of capacity. The average for all manufactured or patented types is very close to \$4.00 per ton of capacity. It must be said in all fairness that the manufactured or patented types generally represent the greatest utility.

IF POSSIBLE, BUILD WITH THE IDEA OF
USING THE SILO FOR A LONG TIME